WATER USE AND MANAGEMENT ASPECTS OF STEAM ELECTRIC POWER GENERATION

A PANEL REPORT

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REPORT TO

THE NATIONAL WATER COMMISSION

THE WATER USE AND MANAGEMENT ASPECTS OF STEAM ELECTRIC POWER GENERATION

by the

CONSULTING PANEL ON WASTE HEAT

May 1972

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16. Abstracts The report assesses the cause, magnitude, and possible effects of heat discharges to water from steam electric power generation and related aspects of condenser cooling system operation. Attention is focused on electrical energy growth and siting requirements, means of more efficiently using electric energy, problems of concentrated heat release, the lack of an adequate environmental research program for determining thermal effects and setting environmental standards, problems related to increased consumptive use of water, the need to more fully consider aspects of steam electric power generation in water resources planning, and the need to establish in national policy a recognition of the waste assimilative capacity of water. The timing and potential impact of technological developments in power generation, condenser cooling, transmission, new siting alternatives, and beneficial and multiple uses of waste heat are assessed in light of their possible effects on reducing waste heat discharge in the near, intermediate and long term. Recommendations are made with the objective of providing better information for making decisions affecting the near to intermediate term. For the longer term, a greatly expanded R&D effort is recommended.

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STATEMENT

This report was prepared by a panel of consultants brought together to provide the Commission with background for its consideration of national water policy issues. The report has not been approved by the Commission but is released at this time through the National Technical Information Service to stimulate public discussion of water resource policy issues. Your comments and suggestions will be appreciated.

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NATIONAL WATER COMMISSION
800 N. Quincy Street
Arlington, Virginia 22203

May 26, 1972

Mr. Theodore M. Schad
Executive Director
National Water Commission
800 North Quincy Street
Arlington, Virginia 22203

Dear Mr. Schad:

Your Consulting Panel on Waste Heat is pleased to submit its report entitled "The Water Use and Management Aspects of Steam Electric Power Generation." The Panel met with representatives of your staff at a series of four meetings during which we discussed the various issues involved in our mission. We arrived at a number of conclusions regarding those issues, and have formulated a body of recommendations for the consideration of the National Water Commission.

As you requested, our attention was confined in this report to problems associated with the effects of heat discharge from steam electric power plant operation on the Nation's water resources. Also as requested, we have generally directed our attention to matters of water policy. However, some of our recommendations concern other aspects of national policy which must be part of the broad viewpoint necessary to adequately address the water issues.

We understand another of your panels has undertaken a study of the Nation's water pollution control program which includes, among other things, water quality planning, the standard-setting process, the antidegradation clause, and the roles of the various levels of government in pollution control activities. We also understand that your forecasting study has considered such things as effluent charges and pricing mechanisms, and that other studies cover a broad range of institutional and legal aspects of water resources. The subject matter in these studies are of concern to us also. In light of these other studies, however, we have concerned ourselves mainly with those specialized aspects which were not addressed by the other groups.

It should be pointed out that our study did not include the development of new data or the performance of any basic research. Use was made of available publications and current studies, and an attempt was made to solicit the views of a number of individuals active in fields related to the issues raised by our Panel.

This report was prepared at our direction by Richard C. Tucker, working under the general supervision of Victor A. Koelzer. While the primary report production was by Mr. Tucker and includes a considerable amount of staff input, we bear responsibility for the basic rationale, ideas, conclusions, and recommendations contained herein. We are deeply appreciative of the cooperation and assistance provided by your staff and by those who were consulted on matters related to the preparation of this report.

There is a strong and shared belief in the need to achieve a balance among developmental and environmental values. The Nation's public and private decisionmakers need to consider as fully as possible the full range of benefits and costs of alternative courses of action prior to the adoption of any particular course of action. This decision process must give full consideration to all resource factors, only one of which is water. This is particularly true for locating future generating facilities. We believe our recommendations, if implemented, will provide the needed base for sound decisionmaking concerning the water resources aspects of heat discharge from steam electric power generation. Such a base is essential if the Nation is to meet its energy and environmental quality requirements in a timely and orderly manner.

We are appreciative of the opportunity to advise the National Water Commission on matters of national water policy. This report should aid the Commission in arriving at its final recommendations to the President and the Congress.

Respectfully submitted,

Peter A. Krenkel
Chairman
Consulting Panel on
Waste Heat

Enclosure
Panel Report

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THE WATER USE AND MANAGEMENT ASPECTS OF STEAM ELECTRIC POWER GENERATION

Introduction

This report deals with a resource allocation question--the use of water for cooling in steam electric power generation plants and the implications of such expanded use upon the preservation and enhancement of the quality of the Nation's waters. The question is examined as a contribution to the development of better mechanisms for optimizing the attainment of several societal goals. One goal is the production of sufficient energy to meet the needs and desires of an expanding population and a growing economy. Another goal, which has taken on considerable importance during the past several years, is the provision of a quality environment for the enjoyment and appreciation of the American people. One of the many problems that will have to be dealt with in the attainment of these goals is the possibility that the release of large quantities of waste heat from the operation of steam electric power plants to the Nation's waters could contribute to environmental degradation if proper mechanisms for dealing with this problem are not developed.

The Panel has identified and described (a) the cause and magnitude of the problem of waste heat discharge to water bodies, (b) the potential for reducing waste heat and/or putting it to productive uses, and (c) other effects on water bodies related to condenser cooling system operation. Based on the conclusions emerging from

this analysis, we have formulated a body of recommendations which, if implemented, we believe will provide a more rational base for decisionmaking concerning the water resources aspects of steam electric power plant siting.

The Waste Heat Problem

All uses of energy, productive or otherwise, end up in the form of heat additions to the environment. This heat appears from both primary and secondary sources--the primary source being that which is waste heat at the time of energy conversion to man's use, and the secondary source being when the energy in one of its multiple forms is finally used to perform a particular function for man.

Of the total energy used in the U.S. today, approximately 80 percent is released directly to the atmosphere and the other 20 percent is released through water into the atmosphere. The Panel addresses itself primarily to that 20 percent which is presently or is planned to be routed directly through water. Furthermore, since steam electric power production presently accounts for about 80 percent of all cooling water use, we believe we have addressed the main cause of the potential waste heat problem. We do wish to point out in passing, however, that atmospheric warming can obviously affect water temperatures.

The problems--potential or existing--caused by large quantities of heat being discharged to the Nation's receiving waters are of

proper public concern. An increasing population desiring a higher standard of living is creating, through the equipment and appliances it uses, a demand for electrical energy which is presently doubling about every 10 years. This demand is translated into the need for additional generating capacity, most of which will depend on fossil or nuclear fuel at least for the foreseeable future. Based on present efficiencies, the heat equivalent of nearly two kilowatt-hours of energy are lost to the atmosphere for every one kilowatt-hour of electricity produced for consumption. Since water is a more efficient medium than air for condenser cooling, a great deal of this heat is being discharged into the Nation's water bodies and from there it is dispersed to the atmosphere and ultimately to outer space. Considerable quantities of water are involved in this process.

Indiscriminate discharge of large quantities of low-grade heat to water poses a possible threat to the aquatic ecological system of the affected water bodies. Consumptive losses attendant to cooling processes may in some areas deplete stream flow to a point where it becomes of critical concern, especially in peak power-low flow periods. Also, there are other aspects of steam electric power plant operation which can affect water quality.

An additional problem, in terms of unwise resources use and

management, is caused by (1) rigid environmental standards[1/] which largely deny the use of the waste assimilative capacity of water, and (2) the inadequate base of knowledge concerning the environmental aspects of resource use.

Furthermore, there seems to be misunderstanding on the part of those developing policy and legislation concerning the nature of heat and its dispersal in water. Heat is different from other substances which can be collected, concentrated, and disposed of under controlled conditions. Heat cannot easily be concentrated in the same fashion, but must be dispersed. Heat can be dispersed to the biosphere in various ways, all of which must be considered in the establishment of policies concerning environmental quality. The National Water Commission recognized this difference insofar as it constituted this Panel to advise it on these matters.

At the outset, the Panel emphasizes its concern over the indiscriminate discharge of waste heat into the biosphere; equally the

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1/ In this report the definitions of the terms "standard" and "criteria" are those adopted by the Federal Water Pollution Control Administration (the statutory responsibilities of which are now under the U.S. Environmental Protection Agency) and given in U.S. FEDERAL WATER POLLUTION CONTROL ADMINISTRATION (April 1968), #15, p. vii.

> "'Standard"--a plan that is established by governmental authority as a program for water pollution prevention and abatement.
>
> "'Criteria'--a scientific requirement on which a decision or judgment may be based concerning the suitability of water quality to support a designated use.
>
> "The standards adopted by the States include water use classifications, criteria necessary to support these uses, and a plan for implementation and enforcement."

Panel views with concern those administrative procedures which indiscriminately prohibit the discharge of waste heat into natural water bodies.

In the following pages we will suggest how these concerns can be mitigated through rational analysis and reasonable national policies.

The Need For Two Perspectives

Early in our deliberations it became readily apparent that two perspectives are needed in viewing this issue and in developing recommendations for future action. One perspective must deal with the near to intermediate term, a period of time during which power plants must of necessity be planned, designed, installed, and operated using currently proven and available technology. This time period, as will be discussed later, is expected to include much of the remaining part of the twentieth century. The second perspective must deal with that future period when research and development efforts might have a significant impact on the means of energy generation and thus the quantity of waste heat discharge. This later period, though less predictable, should provide greater opportunity and flexibility of choice over a broader range of alternative courses of action.

Because of the differences in predictability, these two perspectives are handled differently in this report. Specific recommendations which cover a range of activities are provided for dealing

with the near term. For the longer term, our principal recommendation is for a more aggressive and diversified R&D program to stimulate new product development and to provide better means of energy production which at the same time satisfy environmental objectives.

Waste Assimilative Capacity

Basic to an understanding of the Panel's report is our view of the use of the assimilative capacity of water. The assimilative capacity of water is essentially involved with its ability to purify itself or to dilute wastes discharged into it, thus rendering them innocuous. The waste assimilative capacity may be defined as that quantity of waste that can be discharged to a receiving water under low flow conditions without causing adverse or deleterious effects on the water environment or affecting the designated uses of the receiving water body. This natural process depends upon the hydrologic, biologic, and chemical characteristics of the water body, and obviously the characteristics of the waste(s) discharged.

Using the Nation's water resources to accept waste heat provides two major benefits: (1) water as a dilution, dispersion, and dissipation medium is 4-1/2 times more efficient than air on a weight basis and 42 times more efficient on a volume basis; and (2) the improved efficiency of the cooling process reduces the allocation of other resources required for this function (e.g., the construction

of auxiliary cooling mechanisms are costly, reduce the plant efficiency, and require additional electric power to operate). Furthermore, discharging heat through water systems provides the capability to alter heat discharge patterns to the atmosphere, a point which may be important in the planning and design of our urban centers.

The use of water bodies as an intermediate step in heat discharge to the atmosphere also involves some potential costs. These potential costs appear as possible ecological damage to the aquatic system. The consideration of these benefits and costs involves a decision process to balance conflicting values. The Panel believes such a balancing decision process is important. To arbitrarily disregard one set of costs or benefits, which occurs when the capacity of water to assimilate wastes is denied, is not the kind of decision-making which will enable this and future generations to most effectively manage and use all the Nation's resources.

Rigid environmental standards, which largely deny the waste assimilative capacity of water and which are based on inadequate evaluations of the environmental effects of resource use, do not provide the opportunity to make a rational evaluation such as is suggested above. For instance, the water quality standards contemplated for Lake Michigan covering new power plants allow a point discharge of no more than .5 billion BTU's/hour into the Lake. This corresponds to a plant size of approximately 100 MW for a fossil fuel

plant and 70 MW for a nuclear plant, both being considerably smaller than modern economically sized units. The net effect of these standards would be to require cooling towers for all new power plants regardless of the environmental costs, which in some areas would be quite minimal.[1/]

Conclusion: The waste assimilative capacity of water is a valuable natural resource phenomenon which can, under many conditions, have high utility in effectively diluting, dispersing, and dissipating waste heat. The Panel emphasizes, however, that for protecting various uses of water such as for aquatic life, there is a limit to the use of water for these purposes. Where heat input will adversely affect important aquatic life and/or other environmental values, shares of the total allowable heat input will have to be distributed among the various heat dischargers, who would then have to resort to auxiliary cooling methods.

Recommendation: National water policy and water pollution control legislation should recognize and include provisions for the use of the waste assimilative capacity of water. Both short- and long-run approaches to the waste heat problem should fully recognize the capacity of water to disperse heat.

Total Heat Released

Before continuing with our discussion, we believe it important to point out a problem of possibly greater importance than the specific subject of this study. Of growing concern are the possible adverse effects, especially in the more populated areas, of large quantities of heat released to the atmosphere.[2/] It is becoming increasingly apparent that man affects the climatic conditions of the earth by the release of heat and materials which can, particularly in

1/ WRIGHT, James H (1971), #18.
2/ JASKE RT et al. (1970), #5.

the high heat release areas, change the opacity of the atmosphere.[1/] Measurable climatic modifications from the release of heat and materials include, among other things, increases in mean air temperature, precipitation, and cloud cover. Actions taken to deny the use of water as an interim medium of thermal release tend to increase the total rejection of thermal energy to the atmosphere.[2/] Resources development policy needs to fully consider the long-range implications of these modifications.

It is probable that a value or level of discharge exists beyond which major meteorological impacts will result. While the Panel is not prepared to suggest what this value may be in recognition of the agreement among meteorologists as to the need for much more study and quantification, the problem of total heat discharge would be less acute with dispersal of (1) population and (2) major primary heat sources. It is important that resources policy and planning take these alternatives into account.

Conclusion: The Panel recognizes the possible climatic effects of total heat release and suggests this could be a more significant problem than the discharge of waste heat from power plants to water bodies.

Recommendation: Since dispersal of future population growth and of major primary heat sources are possible alternatives and of potential benefit in total resource management, especially in reducing heat

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1/ LANDSBERG HE (1970), #7.

2/ This occurs because auxiliary cooling methods such as cooling towers reduce overall generation efficiency and therefore require higher heat inputs for equivalent electrical energy output.

release in large metropolitan areas, the Panel recommends that these alternatives be given proper consideration in total resources planning.

Heat Pollution

Shortly after taking office, the Administrator of EPA stated: "Our first priority is to achieve an interrelated approach to the environment."[1/] The Panel agrees that an interrelated approach is necessary and should be the No. 1 priority. We believe, however, that EPA has thus far not achieved this objective with respect to "heat pollution," specifically waste heat discharges. This has been fostered somewhat by Federal legislation which tends to compartmentalize the programs and standard-setting processes for air and water quality. For instance, there are situations where inflexible water temperature standards force the design of cooling towers whose discharges are then unable to meet air quality standards.[2/] Although this is only one, perhaps imperfect, example it indicates a lack of coordinated overview of environmental impact.

Although EPA has undergone an internal reorganization which places air and water under a Deputy Administrator for Media Programs, we still fail to see a much needed coordinated and integrated consideration of proposals to manage the discharge of large concentrated quantities of heat release. We believe such an approach is needed in order to provide a balance among overall environmental quality

1/ RUCKELSHAUS W (1971), #13.
2/ An example is Pittsburgh No. 7 of Pacific Gas and Electric Company.

objectives and pollution control abatement costs. In other words, national policy should not continue to foster the institutionalizing of inflexible policies and practices which are unresponsive to varying circumstances, economic forces, and overall environmental values.

Conclusion: In order to adequately assess the total environmental impact of heat release by a range of possible alternative measures, it is necessary to first recognize and evaluate "heat" as a possible pollutant and then to assess the alternative controlled release mechanisms in terms of their overall environmental impact, including local concentration effects.

Recommendation: EPA should assess the economic and environmental aspects of "heat pollution." This should be done with a view to developing an integrated air-water evaluation of alternative heat release mechanisms with an ultimate objective of establishing standards for controlling heat pollution as a mix of air and water quality standards.

Energy Growth and Siting Requirements

Electrical Energy Growth

In the United States, with a growing population and a growing per capita energy consumption, a continuing demand for energy and particularly new electrical generating facilities seems inevitable.[1/] Electrical energy requirements will undoubtedly continue to grow, even if not at the present rate of doubling every ten years. It was pointed out in one study that "...even assuming near zero population growth, a drop to one-half the present

1/ Energy consumed to produce electricity has increased from 18.7 percent of total energy consumption in 1960 to 26 percent in 1970 and is expected to increase to 41 percent by 1990. See U.S. FEDERAL POWER COMMISSION (1972), #14, p. I-3-4.

rate of growth in individual wealth, and a corresponding 50 percent reduction in the current rate of increase in power use in the next decade, U.S. consumption of electricity will still triple by 1990."[1/] Another study pointed out that reductions in the use of many so-called luxury items in the home will not be highly effective in reducing overall growth.[2/]

Growth in energy consumption has been projected to continue in the future because of two forces: a higher population and an increased per capita energy consumption. Despite the growing national concern for a quality environment, all indications are that these forces will continue in an upward path for the foreseeable future. The uncertainties, of course, are the rates at which this growth will continue. Despite the great concern about population growth, per capita consumption has been and will continue to be the most significant factor. The following points this out quite succinctly:

> "Ninety percent of the growth in power generation in the last thirty years has been caused by higher per capita consumption and only 10 percent by population growth. Were we to consider anything above the 1940 level of electric power generation incompatible with sound environment, we would be unable to tolerate a U.S. population today of more than 20 million, assuming current per capita consumption. Or, taking the present population for granted, we would have to slash per capita consumption by 90 percent."[3/]

1/ LEES, Lester et al. (1971), #9, p. 5.
2/ KOELZER, Victor A & TUCKER, Richard C (1971), #6.
3/ LANDSBERG HH (1970), #8, p. 1.

A significant factor which may affect future electrical energy demand is price. While it is apparent that electrical energy costs will increase, due in part to the additional costs of environmental control measures, it remains to be seen what this will do to demand. In a recent study, the price of electricity was projected to increase by seven percent due solely to the addition of air and water pollution control measures.[1/] Such things as changing the rate structure by withdrawing discounts to volume users, changing existing advertising practices, and the larger question of the availability of energy resources and fuel costs also may affect future demand. But again, the precise effect on demand is not determinable at this point in time.

A question asked by many today is "Do we need all this power?" In order to answer this question, a much more penetrating analysis of the American way of life is needed than is either possible or appropriate within the scope of this study.

There has been much recent attention focused on the need for more information and insight concerning the relationship of energy and the environment in the future. A recent report by the U.S. Office of Science and Technology (OST) stated that:

> "...much more information is needed on the relationship of environmental improvement programs to electrical demand and the overall balance of energy uses in the long term before a basis can be found to decide whether the historical rate of electrical power growth should rise or fall."[2/]

1/ NATIONAL ECONOMIC RESEARCH ASSOCIATES, INC. (1972), #11.
2/ U.S. OFFICE OF SCIENCE AND TECHNOLOGY (1970), #17, pp. 48-49.

The Panel concurs that a great deal more study is needed to better determine factors affecting future energy requirements under alternative assumptions of normal use expectancies. Emerging environmental values, changing life styles, rising costs affecting industrial, commercial, and residential users, and technological developments are among those things which must be factored into electrical energy demand forecasts.

This Panel believes that an ample energy supply can be compatible with maintenance of a quality environment and, indeed, can contribute to its enhancement. While at present, and in the short term, a number of conflicts will exist, the probable development of a number of technologies in the longer term should allow much greater choice and flexibility toward meeting both goals. Furthermore, for the longer term, a number of possibilities exist for changes in energy use patterns. These changes include such things as the substitution of electrified mass transit systems for a good deal of urban transportation needs, the planned beneficial use of waste heat, and recycling of waste products. These and other possibilities will have important implications reaching beyond water resources, e.g., air pollution may be the dominant consideration in many instances. The Congress needs to clearly examine the alternatives available to us today and to chart a course for future action. Implicit in this is the need for a coordinated national energy policy which reflects environmental considerations, including water resources.

Conclusions: 1. Energy, waste heat, and water resources are inextricably bound such that planning and policy development for one is highly dependent on planning and policy objectives enunciated for the others.

2. The Panel believes that major reductions in electrical energy use are unlikely, especially in the near term, and that greatly reduced electrical energy requirements should not be counted on to provide relief to the need for additional generating facilities or subsequently from the waste heat problem, especially for the near term.

Recommendations: 1. In order to be able to more adequately assess future energy needs for the long term, the Panel recommends that the Federal Government fund a broadly-based study to assess the interactive effects of energy and the environment with the view to illuminating a range of alternative futures for this Nation.

2. The Panel recommends that water resources planning and policy formulation be considered in the light of a comprehensive national fuels and energy policy. If this policy formulation is not under way by the time this report is released, we believe it should be undertaken.

More Efficient Energy Utilization

Regardless of future life styles and electrical-energy requirements, it is apparent that present methods of ultimate energy use are not nearly as efficient as is practically possible. The use of electrical energy is no exception. While reductions in these inefficiencies will not alone solve the problems of energy release and waste heat dissipation, they are worthy of careful attention since they would mitigate these problems and contribute to better allocation of scarce natural resources and could, in the longer term, affect the rate at which new generation facilities are installed.

For instance, the development of more efficient energy-consuming

appliances such as microwave ovens and stoves, ultrasonic dishwashers and washing machines, electro chemiluminescent lighting panels, thermoelectric refrigerators and air-conditioners, etc., would reduce total national electrical energy requirements. Stricter requirements for insulation in building construction and more efficient space heating would also result in more efficient utilization of the electrical energy produced for heating and air conditioning. Reflective windows to reduce energy losses have also been identified.[1/]

It must be recognized, however, that at present it is not clear whether, in terms of total resource use, more efficient insulation, for instance, might be a more serious depletion of resources than the resources needed to produce the additional energy needed with less efficient insulation. Neither does minimum electrical energy use mean optimum use of resources. Nevertheless, total energy consumption is and should be considered an important factor in the design of those things which in the past have been designed with little attention to the long-term total costs (as distinguished from the first cost of construction or production).

We believe a significant step toward more efficient energy utilization would be a formal directive to the Federal agencies to give greater consideration to energy requirements in the development

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1/ There are opportunities for more efficient energy use also through such things as the total energy concept, beneficial and multiple uses of waste heat, and supplemental energy sources. See p. 60-65.

and adoption of technological and building systems having large electrical energy components. This could be accomplished through its wide and diversified federally supported R&D programs, as well as through requirements governing the design of Federal facilities and facilities designed primarily for the use of the Federal agencies such as rented office space. We recognize that the U.S. Department of Housing and Urban Development has issued, presumably in response to a Presidential message to the Congress calling for fuel conservation, new standards for insulation applied in new federally insured homes with the objective to conserve fuel by reducing heat loss. This is a step in the right direction. We believe a Presidential Executive Order directed to all Federal agencies would be an important next step.

Conclusions: 1. Present electrical energy-using equipment and appliances are far from the most efficient possible, even under presently known technology.

2. Much present-day building construction and appliance manufacturing employ designs with a relatively low first cost and with a resultant high energy consumption, as opposed to a higher first cost and subsequently a lower long-term energy usage.

Recommendation: The President should direct the agencies of the Federal Government to give greater consideration to efficient use of energy, particularly in the development and adoption of technological and building systems having large energy components.

Electrical Energy Forecasts

A range of forecasts of electrical energy requirements have been made by a number of responsible bodies.[1/]

1/ For a review of selected U.S. energy forecasts, see BATTELLE MEMORIAL INSTITUTE (1969), #1.

Perhaps the most broadly-based forecast is that made by the Federal Power Commission (FPC) with the assistance of six regional advisory committees representing all segments of the power industry. That forecast is given in Table 1. While not attempting to review current electrical forecasts in any detail, the Panel is generally familiar with the basis for the FPC forecast and believes that the types of investigations made in developing it are appropriate for "most probable conditions" for the next 20 years. We therefore think they should be used as a point of departure for projecting future requirements for generating capacity.

An important point with respect to future demands for electrical power is that changes from projected figures will only shift the timing of required decisions. While one advantage to delaying the timing would be the possibility of new technologies coming into use in the meantime, we do not believe this advantage will prove to be of great significance over the short term. The possibilities over the longer term are obviously greater.

Another important fact is that the peak electrical energy demand in many regions has shifted from the winter to the summer season largely because of the greatly increased use of air conditioning. This is especially important for consideration of water problems, because unfortunately the summer season is generally the period of low river flows, high water temperatures, and decreased waste assimilative capacity. This combination of factors tends to exacerbate the waste heat problem.

Table 1[1/]

PROJECTED GROWTH OF UTILITY ELECTRIC GENERATING CAPACITY
(Figures in thousands of megawatts)

Type of Plant	1970 (actual) Capacity	1970 (actual) % of Total	1980 Capacity	1980 % of Total	1990 Capacity	1990 % of Total
Hydroelectric-conventional	52	15	68	10	82	7
Hydroelectric-pumped storage	4	1	27	4	71	6
Fossil steam	260	77	393	59	557	44
Gas-turbine and diesel	19	6	31	5	51	4
Nuclear	6	2	147	22	500	40
TOTALS (rounded)	340	100	665	100	1,260	100

Notes: (1) These projections are keyed to the electrical energy demand projections made by Regional Advisory Committee studies carried out in the 1966-1969 period.
(2) The projections are premised on an average gross reserve margin of 20%.
(3) Since different types of plants are operated at different capacity factors, this capacity breakdown is not directly representative of share of kilowatt-hour production. For example, since nuclear plants are customarily used in base-load service and therefore operate at comparatively high capacity factors, nuclear power's contribution to total electricity production would be higher than its capacity share.

1/ U.S. FEDERAL POWER COMMISSION (1972), #14, p. I-1-17, 18.

Probable Numbers and Sizes of Future Plants

The pattern of future site development will tend to fewer and larger plants than has been the case in the past. OST described the present situation by reporting that:

> "...the existing 300,000-mw capacity is located in more than 3000 separate plants.... Of the 3000, about 140 plants have total installed capacities exceeding 500-mw."[1/]

The FPC has estimated that a total of approximately 492 sites will be needed by 1990 for thermal plants of greater than 500 MW (these sites are expected to account for approximately 95 percent of installed steam electric power plant capacity).[2/] Of this number, it was estimated that approximately 255 will be new sites, with 91 and 164 projected to be fossil fuel and nuclear plants, respectively. The majority of these plants were estimated to range in size from 1,000 to 4,000 MW with the largest possibly approaching 10,000 MW. It is quite possible that in the future new technologies and new philosophies of energy generation will focus attention in some areas on the opportunities of smaller central station generation and localized energy systems. These potentialities, however, are not likely in the near and intermediate terms.

The potential of larger sized plants only heightens the potential problems of waste heat concentration. This is because of both larger point sources of heat discharge and the possibility that

1/ U.S. OFFICE OF SCIENCE AND TECHNOLOGY (1968), #16, p. 5.
2/ Ibid., pp. 4-5.

local water supplies will not be able to support the increased consumptive losses or have the capacity to assimilate the heat.

Waste Heat and Cooling Water Requirements

The type of generating facility, the plant heat rate (i.e., efficiency), the inlet water temperature, the design temperature rise across the condenser, and the type of cooling method used are the important factors involved in determining both the total quantity of heat that will be released and the cooling water requirements.

Waste Heat From Steam Electric Power Plants

Table 2 presents a comparison of the typical heat and cooling water characteristics of different types of steam electric power plants.

In contrast to the very large growth in electrical energy production, there have been only modest increases in thermal generating efficiency over the past 15 years.[1/] The thermal efficiencies of modern fossil fuel and nuclear power plants generally range between 33 and 40 percent. In other words, 60 to 67 percent of the heat generated is nonproductive and is rejected to the biosphere as waste heat.

1/ While the efficiency of the most efficient plants recently constructed is increasing somewhat, the overall average thermal efficiency on a national scale has flattened out, particularly over the past five years.

Table 2

HEAT CHARACTERISTICS OF TYPICAL STEAM ELECTRIC PLANTS
(Heat values in BTU per kwh)

Plant Type	Thermal Efficiency (Percent)	Required Input (Heat rate)	Total Waste Heat (Required input minus heat equivalent) 1/	Lost to Boiler, Stack 2/ (etc.)	Heat Discharged to the Condenser	Cooling Water Requirement (Cubic feet per second per megawatt of capacity) 3/
Fossil fuel	33	10,500	7,100	1,600	5,500	1.6
Fossil fuel (recent)	40	8,600	5,200	1,300	3,900	1.15
Light water reactor	33	10,500	7,100	500	6,600	1.9
Breeder reactor 4/	42	8,200	4,800	300	4,500	1.35

1/ The heat equivalent of one kilowatt-hour of electricity (kwh) is 3,413 British thermal units (BTU).
2/ Approx. 10 to 15% x required input for fossil fuel.
Approx. 3 to 5% x required input for nuclear.
3/ Based on an inlet temperature in the 70°s F. and a temperature rise across the condenser of 15° F.
4/ Included for purposes of comparison--see Table 3 (p. 25) for the Panel's estimate of the date the first major unit is expected to be in operation.

In fossil fuel plants, a portion of this nonproductive heat is discharged directly to the air through the boiler and stack, as indicated in Table 2, but the majority is released to water through the condenser cooling system after which the heat is dissipated either directly or indirectly to the atmosphere (depending on the cooling method used). In a nuclear plant, however, there are no stack losses and in-plant losses are minimal, leaving nearly all the waste heat to be discharged through the condenser cooling system. For example, a typical modern (40 percent efficient) 1,000 MW fossil fuel plant has a once-through cooling water requirement at full plant operating capacity of approximately 1,150 cfs (832,600 acre-feet per year) corresponding to an inlet temperature in the 70°F and a water temperature rise across the condenser of 15°F. For a similar sized conventional (33 percent efficient) light water reactor, 1,900 cfs (1,375,600 acre-feet per year) would be required to provide the same rise. This simple comparison of plant types indicates that because of efficiency differences and heat release characteristics, the development of more light water reactor capacity, while advantageous from a number of other viewpoints, will only increase waste heat discharges to water and therefore increase cooling water requirements.

The Potential For Reducing Waste Heat

Although the initial cause of much waste heat discharge is the demand for more electric power, once the decision has been made that a steam electric power plant is to be

constructed to meet an increment in demand, the factor which determines the quantity of waste heat produced is the efficiency of the generating facility. Therefore, and in full consideration of the second law of thermodynamics, an increase in average plant efficiency is needed to reduce the waste heat release to the environment. Although, as shown in Table 2, the type of generating facility affects the amount of heat lost through the condenser cooling system, efficiency is the key in attempting to reduce or eliminate any potential problems caused by discharging heat to the Nation's water bodies.

In order to assess the possibilities of reducing waste heat discharge from new technologies in electrical power generation, the Panel estimated the most probable technologies in use through the end of the century, and for each method of generation, its most probable share of the Nation's electrical generating capacity in the year 2000.[1/] These estimates appear in Table 3. Also shown are the Panel's estimates of when each new generation technology will first come into practical use under both present and accelerated R&D.

We expect nearly two-thirds of the Nation's generating capacity in year 2000 to be comprised of systems presently in widespread use, i.e., hydroelectric power (five percent), fossil fuel generation (20-35 percent), and light-water nuclear reactors (30-40 percent). The remainder would then be comprised of new technologies, i.e., nuclear

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1/ For a discussion of new technologies, see p. 54.

Table 3

ELECTRICAL POWER GENERATING TECHNOLOGIES

Method of Generation	Fuel Used	Avg. Thermal Eff. of Plants Built in 1990-2000 Period 1/	Heat Disc. to Cond. Cooling Water BTU/KWH	Date First Major Unit Could be in Operation: Present R&D Funding	Date First Major Unit Could be in Operation: Accelerated R&D Funding	Expected % of Total Capacity Year 2000
PRESENT SYSTEMS						
Hydroelectric (Conventional & pumped storage)	Water	--	-0-	SOA		5
Fossil Fuel 2/	Coal, Oil, Gas	~42%	3,900	SOA		10 - 20
Shale Oil, Coal Gasification & Coal Liquification (new fossil fuel)	Oil & Gas	42%	3,900	1995	1985	10 - 15
Internal Comb. Eng.	Oil	25-35%	-0-	SOA		<1
Gas Turbine	Gas, Oil	20-30%	-0-	SOA		<1
Topping G.T. w/Waste Heat Boiler	Gas, Oil	40%		SOA		<1
Light Water Reactors	Uranium & Thorium	~33%	6,600	SOA		30 - 40
DEVELOPING SYSTEMS FOR THE SHORT TERM (1970-2000)						
Gas Cooled Reactors	Uranium & Thorium	~40%	4,800	SOA		10 - 20
Nuclear Breeders	Uranium & Thorium	38-42%	4,500	1990	1985	10 - 15
Fuel Cells 3/	Partially Oxidized Coal, Oil & Gas	60%	-0-	1985	1980	<5
EGD	Nat. or Manuf. Gas	40-55%	-0-	Never	1990	<5
MHD	Fossil or Nuclear	55%	-0-	Never	1990	<5
MHD Topping Cycles	Fossil or Nuclear	60%	1,700	Never	1990	<5
Geothermal	Geothermal Energy	20-30%		SOA		<1
DEVELOPING SYSTEMS FOR THE LONG TERM (After 2000)						
Thermoelectricity	Any Heat	10-15%		Indefinite		0
Thermionic	Any Heat	10-30%		Indefinite		0
Fusion	Hydrogen or Helium (seawater)	75-95%	Small	Never	2010	0
Solar	Sun's Energy	14-25%		Never	1990	<1

SOA - State of the Art

1/ Where SOA, the efficiency given reflects the Panel's estimate of improvements in state of the art technology.

2/ Conventional fossil fuel, excluding shale oil, coal liquification and gasification

3/ Not Central Station

breeders (10-15 percent), gas cooled reactors (10-20 percent), and other methods (five percent).

To understand the Panel's reasoning concerning the timing and impact of new technologies, it is necessary to consider the time lag between development of a new technology and its use on a broad commercial basis. Two time elements are involved: (1) the time lag between development on a proven research basis and the time of commercial availability, and (2) the time lag between availability and widespread use. The first relates to proving technical and economic practicality, the second to developmental, regulatory, and licensing and construction lead times. Because of these time lags new technological developments in generation will have little overall impact on increasing the efficiencies of plant systems put in operation through the year 2000, regardless of new technologies that research and development may bring forth prior to that time. These time lags also apply to transmission, cooling, and beneficial and multiple use technologies; however, the times involved may be shorter.

Conclusions: 1. Research and development will not have any appreciable impact on thermal efficiencies of plants constructed through much of the remaining part of the twentieth century. That is, the heat discharges, indicated in Table 2, are representative of what should be expected from most of the steam electric power plants which will be constructed between now and the end of this century.

2. Although breeder reactors will increase efficiency of nuclear plants, their increased efficiencies will be still not significantly beyond the 40 percent efficiency that represents the upper end of the current range.

3. Clearly, additional emphasis must be placed on developing more efficient basic power cycles.

4. It is obvious then, given that large quantities of waste heat will be discharged, that emphasis for the short term should be placed on learning how to release the heat in an environmentally compatible manner.

Cooling Methods

Given that a certain amount of heat will be nonproductive, the problem is how to release this heat to outer space without causing undesirable environmental impacts as it travels through the biosphere. Since water is used for condenser cooling, the problem here becomes one of dissipating the heat added to the water through some type of cooling process. A number of cooling methods are available.[1/] The most commonly used, singly or in combination, include:

(1) The once-through or run-of-river system where water is discharged directly to a receiving water without auxiliary cooling.

(2) Cooling ponds or canals where water is discharged to a holding area to be cooled, from which it may be discharged directly to a water body or recirculated through the condenser cooling system. These may include spray systems which serve to increase the heat loss per unit area.

1/ For a review and comparison of cooling methods, see PARKER, Frank L & KRENKEL, Peter A (1969), #12, Chapters IX-XII, and NATIONAL ACADEMY OF ENGINEERING (1972), #10, pp. 103-136.

(3) The cooling tower where water is cooled using wet or dry and mechanical or natural draft means after which it is discharged to a water body or recirculated.[1/]

Although most cooling systems generally use either fresh or saline water, other sources such as sewage treatment plant effluent have been used on a limited basis.

Each method has a range of costs and benefits and a different effect on water.[2/] For example, the once-through method requires a

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1/ Mechanical draft towers use fans to induce or force air movement. Air movement in a natural draft tower results from a chimney effect created by the difference in density between the air inside the shell and the air outside. Heat transfer in a wet tower occurs through evaporation while in a dry tower it occurs through conduction and convection.

2/ A key to understanding the possible impact of the operation of the condenser cooling system of a steam electric power plant is an understanding of the terminology. There are three major flow values with which to be concerned: Condenser cooling flow requirement, withdrawals, and consumptive use. The first is the amount of water which is required to flow through the condenser cooling system and is dependent on the type of plant, the plant efficiency, the inlet water temperature, and the desired temperature rise across the condenser (this is the last column of figures in Table 2). This is distinguished from the second flow value, withdrawal (from either fresh or saline sources), which varies with the method of disposing of the heated water: In a once-through system it would equal the condenser cooling flow requirement, but in a recirculating cooling tower system it would only equal makeup water requirements, i.e., blowdown, drift, leaks, and evaporation. Consumptive losses, the third value, equal the amount of water lost from the local water regime, a major part of which is evaporation. Consumptive losses are primarily dependent on the method of dissipating the waste heat. It should be noted also that while a total withdrawal quantity for the Nation or a region (the way in which withdrawals are frequently given) gives an order of magnitude of water requirements, much more information on local impacts is needed in order to assess hydrologic impact by region, subregion, and river basin.

considerable withdrawal and discharges nearly all the waste heat to the receiving water with minimal consumptive use; wet cooling towers while requiring relatively little in the way of withdrawals and discharging no heat directly to the water are high consumptive users of water and are quite costly; dry cooling towers require practically no withdrawals, have practically no consumptive use, discharge no heat directly to the water, but are presently by far the most costly of cooling methods.

The decision as to which methods to employ in any given situation should be made on the relative basis of total system capital and operation and maintenance costs including energy requirements for cooling equipment operation, the effects of heat discharge to the receiving water (including environmental standards), consumptive use of water, and atmospheric impacts. There is obviously no single rational solution for all cases; the decision on how to handle the waste heat discharge for each plant is site-specific. It is important, however, to evaluate the available alternatives for each site from a broad consideration of all resources, costs and benefits, especially capital and operation and maintenance requirements, and environmental effects.

Cooling Water Requirements

It is difficult to provide a useful perspective on cooling water requirements as requirements vary

considerably according to range of assumptions. As an example, the FPC has attempted to show how required withdrawals, consumptive use, and cooling system costs could change under a range of assumptions about possible environmental standards which the Nation might choose.[1/] Estimates were prepared for each of the six Regional Advisory Committee areas for the 1980 and 1990 periods based on the projected growth in generating capacity given in Table 1.

To demonstrate the influence of varying thermal water quality standards on the requirements for cooling facilities and cooling water, three planning assumptions were tested:

> "Study A was made on the assumption that compliance with thermal criteria comparable to those suggested by the National Technical Advisory Committee would adequately protect the quality of water bodies.[2/] This would include the use of properly designed mixing zones of carefully delineated, limited areas. However, no site would be considered available for once-through cooling use until thorough biological and other relevant studies had been completed and the projected effects were shown to be within acceptable limits.

1/ U.S. FEDERAL POWER COMMISSION (1972), #14, p. I-10-16.

2/ The National Technical Advisory Committee on Water Quality Criteria was established by the Secretary of the Interior on February 26, 1967. Its principal function was to collect into one volume a basic foundation of water quality criteria. The criteria were set out as guidelines only, to be used in conjunction with a thorough knowledge of local conditions. See U.S. FEDERAL WATER POLLUTION CONTROL ADMINISTRATION (1968), #15.

Study B was made on the assumption that the thermal criteria suggested by the National Technical Advisory Committee, including appropriate mixing zones, would prove to be inadequate for protecting the quality of water bodies. Thus, each plant or plant addition constructed after 1970 would be expected to require a cooling pond or an evaporative cooling tower unless it could utilize water from the ocean, with a long outfall.

Study C was made on the assumption that each plant operating in 1980 and 1990, regardless of when constructed, would be expected to require a cooling pond or an evaporative cooling tower unless it could utilize water from the ocean, with a long outfall. This would require the backfitting of plants constructed without such facilities."

The results of these analyses, aggregated from the six regional areas, are contained in Figures 1 and 2. Figure 1 indicates the impacts on withdrawals and consumption use. Note especially that as withdrawals decrease, consumptive use increases. Figure 2 indicates the impacts on capital and operation and maintenance costs.

Gross figures on a national or regional basis provide only a general order of magnitude of water use for steam electric power generation. While the FPC analyses are useful to show how cooling water withdrawals, consumptive use, and costs depend on the type of environmental standards chosen, they provide no insight on the

ESTIMATED COOLING WATER REQUIREMENTS FOR PROJECTED STEAM-ELECTRIC PLANTS – 1,000 CFS

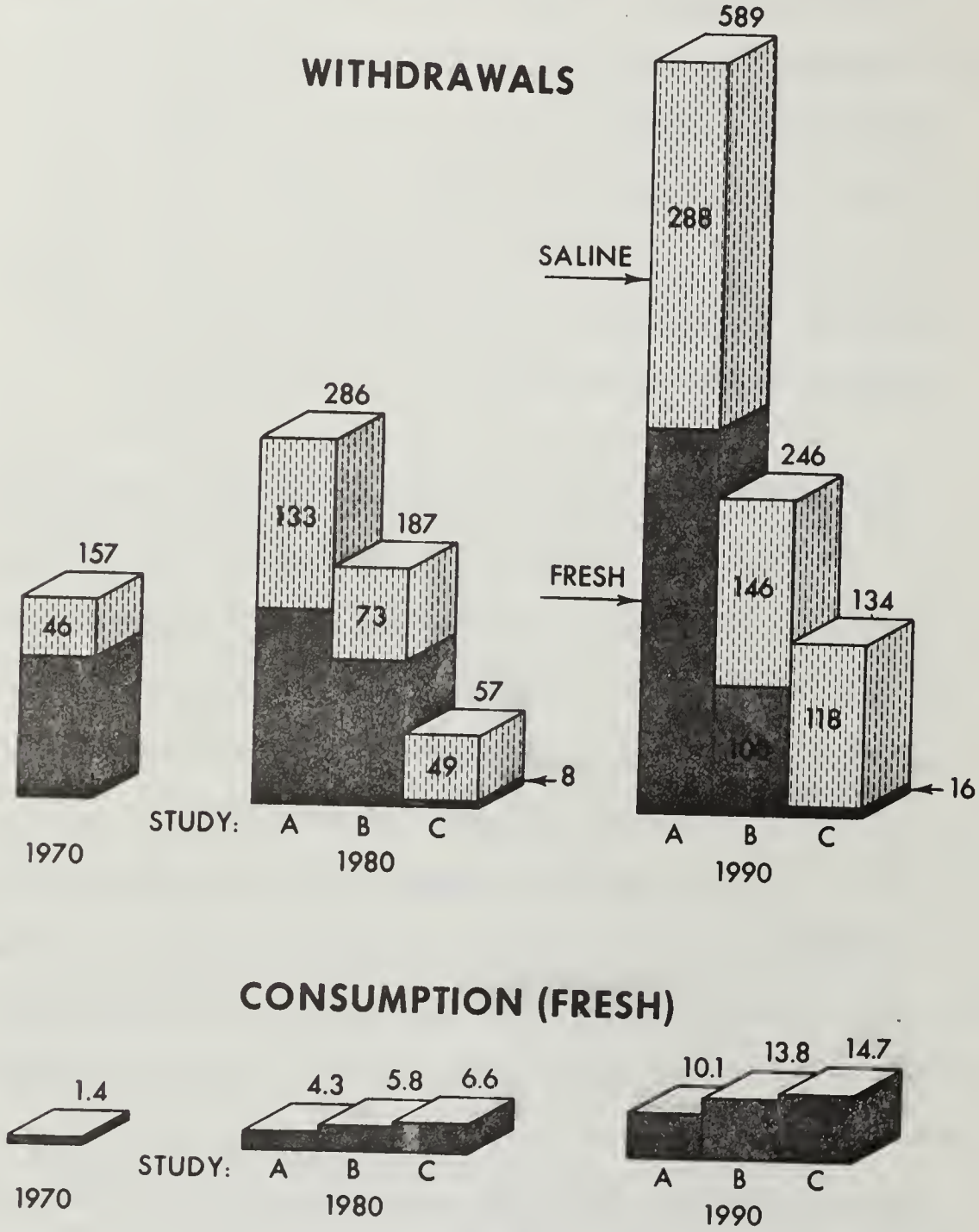

Figure 1

ESTIMATED COSTS OF COOLING WATER FACILITIES BILLIONS OF DOLLARS

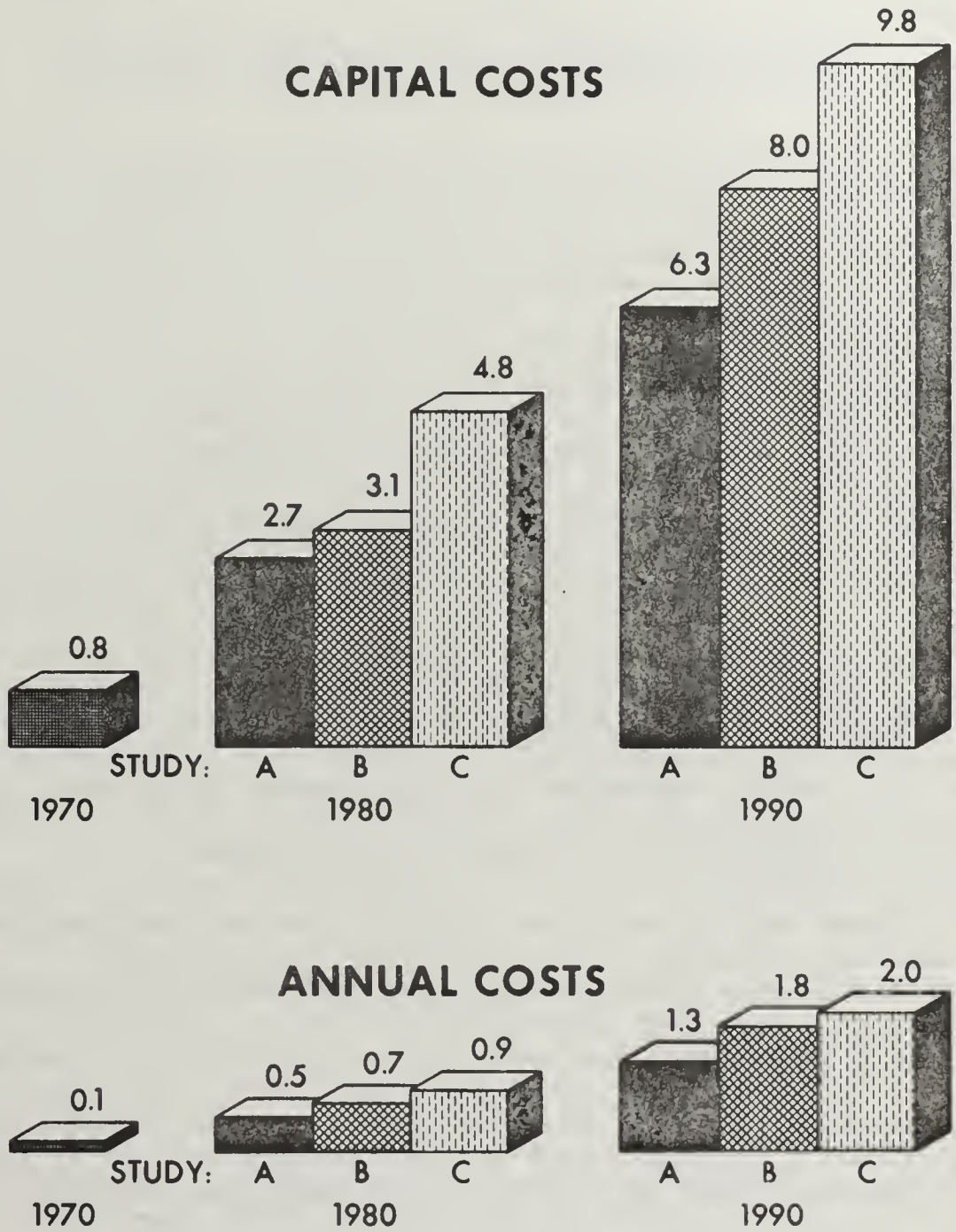

Figure 2

sensitivity of these factors to environmental standards by river basin or reach of river. We believe that steps must be taken now to assess on a smaller areal basis these water use aspects associated with a range of environmental standards. This is particularly important with respect to consumptive use.[1/]

Effects of Steam Electric Power Plant Operation On the Water Environment

Thus far we have dealt primarily with the sources of waste heat discharge. Now we turn to the effects, which form the basis for an identified problem.

Temperature is one of the most, if not the most, important single factors governing the occurrence and behavior of life. The effects of heat discharge from power plants are therefore the most pervasive of all the various effects of condenser cooling. Furthermore, as we discussed in the preceding section of our report, the consumptive losses attendant to various cooling systems might in some areas deplete streamflow to a point where it becomes a critical concern, especially in peak power-low flow periods.

Various other aspects not directly concerned with heat but intimately related to the operation of condenser cooling systems also merit attention. Chemicals used to facilitate the cooling process, metal loss from corrosion and/or erosion, and mechanical and hydraulic effects of cooling system design and operation can have

1/ See "Consumptive Use," p. 42.

detrimental environmental effects. A number of these effects can be minimized by proper engineering design and site selection.

Effects of Temperature

The discharge of heat to a body of water can cause a number of physical, biological, and chemical effects. As water temperature is raised, the oxygen-holding capacity of the water decreases, the reaeration rate rises, density changes may cause stratification, evaporation is increased, chemical, biological, and physical reactions tend to be at a faster rate, and viscosity decreases, which reduces the sediment transporting ability of the water. These changes, of course, can be beneficial, detrimental, or insignificant depending to a great extent on the desired uses of the receiving waters.

There could be a variety of impacts. Heat increases the rate of BOD exertion which, when combined with a reduced rate of reaeration, temporarily lowers a stream's organic waste assimilation capacity. The addition of heat in the winter months could lengthen the shipping season by elimination of lock jamming and potentially shortening the period of ice cover in the shipping lanes. Discharge of heat in colder waters could also be beneficial for other uses.

The greatest potential impact of heat discharge to water, however, is on aquatic life. Discharges of large quantities of low-level heat relative to the waste assimilative capacity of the receiving waters could have severe effects on the ecosystem into which they are discharged.

A large number of studies have been and are being conducted on this subject.[1/] Although a great deal of additional *in situ* study must be made of specific aquatic species and their tolerance ranges and a large number of gaps must be filled in an attempt to understand cause and effect relationships, a number of basic relationships are fairly well understood.

Temperature changes have a direct effect on such things as metabolism, reproductive cycles, behavior, and digestion and respiration rates. Adverse effects can be lethal as well as sublethal. Mortality can occur because of the exceedence of maximum temperature tolerances, as well as from too rapid increases or decreases in temperature. A shift in population structure that affects specie diversity can have a substantial impact on ecosystem stability. This can occur throughout the food web, from plankton, periphyton, filamentous algae, rooted aquatic plants, invertebrates, to fish. Since fish are at the apex of the aquatic food pyramid, any drastic change in any part of the pyramid will be reflected in changed fish population and/or specie diversity. The more we learn about these effects the more knowledgeable will be our decisionmaking concerning the effects of power plants on the water environment.

Although a great deal of study has been conducted, it is presently very difficult to organize the wealth of information available

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1/ For a listing of recent literative surveys and bibliographic compilations, see NATIONAL ACADEMY OF ENGINEERING (1972), #10, p. 139.

into a usable readily retrievable form. There is also little consistency among investigators in the method of determining temperature effects on aquatic life. In addition to it being very difficult for a potential user to obtain needed information concerning possible thermal effects, there is no orderly feedback mechanism whereby research needs are communicated to those who are doing the research. In a field of interest such as this, critical decisions affecting vast public and private expenditures, and major environmental impacts are in need of the most current knowledge.

The Panel believes that a computerized information retrieval and data center is needed to serve as a clearinghouse for information concerning the ecological aspects of steam electric power plant operation. This data center could be attached to a number of existing institutions such as (1) the research and monitoring office of EPA or (2) the U.S. Department of the Interior's Water Resources Science Information Center. A good approach would be to establish regional centers which could be connected to a systems central somewhat like the recently proposed National Water Data Exchange or as outlined in the proposed legislation calling for a National Environmental Data System. We believe such a system could be developed by the task force recommended herein.

Recommendation: A computerized information retrieval and data center should be established to serve as a clearinghouse for already available information and the information hopefully to be developed as outlined in the remainder of this section.

In addition to the problems of organizing, retrieving, and disseminating information, a review of testing methods, environmental survey procedures, and regulatory standards reveals a lack of standardization of sampling and measurement technology in determining temperature effects on biota. Such standardization would prove quite valuable for those in research, those in the utility industry, and those in the regulatory agencies as a means of assuring a common base in setting criteria and standards.

Recommendation: Standard methodologies should be formulated for sampling and measuring the effects of temperature on aquatic life. This would also aid immeasurably in the development of the information system recommended above. We recommend that the implementation of this be part of the research effort outlined in the recommendations on page 41.

We understand that the National Water Commission's Panel on Water Pollution is reporting on the standard-setting process, water quality criteria, and related matters. We do not wish to duplicate this analysis. We do, however, wish to emphasize the extreme importance of flexible water quality standards and standardized methodology, especially as regards the establishment of temperature criteria.

In setting temperature criteria, a range of factors such as temperature rise, temperature tolerances, total heat input, mixing zones and passageways, exposure time, seasonal variability, and geographical and hydrologic characteristics, all must be considered. We stated previously that either indiscriminate heat discharge or total prohibition of heat discharge are unwise policies for this

Nation to follow. The question then is how much temperature rise and/or heat input to allow in any specific water area. Unfortunately, this question has no single answer because of the great variability in ecosystem response and the desired use of the water body.

While it is not the role of this Panel to suggest what the uses of various water bodies should be, it is our desire that the best possible information be available to facilitate rational decisionmaking. We believe that the present method of establishing temperature criteria and standards is based, unfortunately, on neither a well funded and coordinated research program nor an adequate recognition of geographical, hydrological, and seasonal differences as well as diverse ecological systems, nor on a recognition of the waste assimilative capacity of water. We recognize (1) that when temperature criteria were, and for certain states are now, being formulated, it was only possible to base their development on limited data on temperature effects; and (2) that rarely if ever is enough information known or available on which to base any judgment. However, we believe there should be an expanded and systematic research effort to fill the gaps, to recognize the differences mentioned above, and to continually review and revise temperature criteria and standards as more definitive information becomes available.[1/]

1/ The U.S. Environmental Protection Agency has contracted with the National Academy of Sciences (NAS) to update and revise the report of the National Technical Advisory Committee on Water Quality Criteria which was mentioned earlier. The NAS report is scheduled for publication this year.

Since there are existing organizations capable of managing a program such as is suggested herein, we see no need to establish another government agency or industry group. We do, however, see a need to bring existing agencies and industry groups[1/] together in a formal continuing relationship for the purpose of managing and funding the ecological research program recommended herein. We believe that such an effort needs to be structured in such a way as to maintain high professional and scientific standards and to maintain credibility for all interests concerned. This view is generally supported by a recent OST report[2/] which states that:

> "...ecological research of general interest may be funded by the federal government with the assistance of utility organizations. Where such studies form the basis for establishing standards and criteria, <u>it is important that the work be supported by an objective organization</u>. In instances where the results of specific ecological research are necessary to provide data needed by a utility to resolve questions about a particular plant it is appropriate that the individual utility accept the responsibility for supporting the research and development and obtaining the necessary information."[2/] (Underlining added)

We emphasize that in order to adequately carry out this work there will be an increasing need for trained professionals in quantitative biology and applied ecology. We suggest that this need be brought to the attention of those on the National Water Commission staff who are addressing the manpower and training aspects of the Commission's program of studies.

1/ The electric utility industry funding could come from such industry groups as the Edison Electric Institute (EEI), The American Public Power Assocation (APPA), the National Rural Electric Cooperative Association (NRECA), and perhaps jointly through the Electric Research Council (ERC).

2/ U.S. OFFICE OF SCIENCE AND TECHNOLOGY (1970), #17, p. 42.

Conclusions: 1. The Panel concludes that a more systematic and flexible environmental research program is needed to provide the kinds of information, particularly with respect to the effects of temperature and temperature change on aquatic life, on which rational standards may be set and on which informed decisionmaking may be based.

2. A properly coordinated and funded approach (including information from the pre- and post-operational studies discussed on page 48) is needed to delineate for each of the general ecologically representative aquatic systems in the U.S. (the Panel estimates these to number approximately 20), the optimal, sublethal, and lethal temperature levels for aquatic life, including such things as acclimatization, seasonal patterns, time of exposure, etc. This should be subject to continual review and modification as appropriate.

3. While the Panel believes this should be a coordinated national effort, we emphasize that there should not be national temperature standards, but rather regional or water body criteria based on ecologically representative systems as indicated above.

4. In order to effectively implement such a program there needs to be a much greater emphasis on training people in quantitative biology and applied ecology.

Recommendations: 1. The Panel recommends that a national program be established to provide the information referred to above.

2. We recommend that in order to maintain credibility among all concerned, a state-Federal-industry task force be established and charged with the responsibility for coordinating, managing, and continually updating this research program.

3. We recommend that the program be jointly funded by the Federal Government and the power industry, perhaps through such groups as EEI, APPA, NRECA, and ERC.

4. We believe that the kinds of research needed in such a program should be undertaken by properly qualified applied research institutions which are mission-oriented. In order to maintain objectivity this should include a greater emphasis on commercial firms than has been the case in the past.

5. The Panel recommends that the need for trained manpower as identified above be brought to the attention of those on the NWC staff who are addressing this aspect of the NWC's program of studies.

Consumptive Use

A major effect of using water for condenser cooling is the loss of water to the local water regime, termed consumptive use, which accompanies any evaporative cooling process.[1/] Its magnitude is primarily dependent on the cooling system selected and therefore, especially in water-short areas, should be a significant consideration in cooling system design. An examination of a number of recently completed water resources investigations indicates that evaporative losses from steam electric power generation are projected to increase substantially and with other uses are likely to cause water shortages in the intermediate to long term in some areas.[2/]

Conclusion: The evaporation of extensive quantities of water represents a possibly serious diversion of water, especially in the Nation's water-short areas, and during peak power-low flow periods.

Recommendation: Planning for regional power systems should take into account these possible modifications in the normal hydrology. Full consideration should be given to the relative merits of cooling systems which evaporate considerably less water. (See also Recommendation on p. 54) Furthermore, water quality standards should be set with careful consideration given to the quantitative aspects of consumptive use.

1/ Consumptive losses are on the order of one percent of condenser flows for once-through cooling, one and one-half percent for cooling ponds, and approximately two percent for evaporative cooling towers and spray ponds. For example, for a 3,000 MW light water reactor, consumptive losses would approximate 54, 81, and 108 cubic feet per second or, expressed another way, 40,000, 60,000, and 80,000 acre-feet per year, respectively. On the other hand, consumptive losses are negligible for the costliest of cooling methods, the dry cooling tower.

2/ Among others, the Missouri and the Ohio are examples of river basins needing particularly careful study in this regard.

Other Effects of Cooling Methods

A number of chemicals are used in conjunction with various cooling systems.

In plants using once-through cooling, chlorine which may cause damage to the biota is sometimes added to prevent fouling of the condensers. The possibility of damaging effects is more critical in estuarine and marine areas than in lakes which are in turn more critical than in riverine systems.

Recommendation: Emphasis in research should be placed on developing defouling methods which are at least as effective as chlorine but which have little or no impact on the water environment.

The method and timing of passage of water through the plant cooling system is also important. Cooling water intakes for any system should be designed so as to avoid the trapping of mobile species. Improved screening methods should be employed in future cooling water systems to accomplish this. Also, designs should emphasize short travel and exposure times for biota, especially entrained organisms, passing through the cooling system. The Panel emphasizes that high temperature rises are not intrinsically bad if exposure times are short and the effluent dispersion is carried out rapidly within limits acceptable to the key species involved. In addition, the design and construction of discharge outlet structures must take into account their possible adverse effects due to high velocity currents and scour.

While the Panel has no specific policy recommendations relating to the above, we believe these kinds of considerations must be given

much more attention and that engineering and system designs should be modified appropriately to minimize ecological damage.

Effects of Cooling Towers on the Environment

A great deal of concern is expressed about the possible adverse ecological, climatological, and esthetic impacts of various cooling techniques, particularly cooling towers. Some concern is expressed through purely subjective evaluation, such as the esthetic effects of cooling towers on the landscape. Other aspects can be given more quantitative analysis, particularly with respect to such things as consumptive use and cost.

Perhaps the greatest divergence of opinion occurs on the effects of cooling towers on local climate through vapor plumes, induced fog, precipitation, and icing. The Panel agrees that these effects are possible. A problem in the past has been inadequate consideration of climatological and meteorological factors in plant location and cooling tower design. For instance, there is a much higher potential for problems if power plants are located in areas of high smog and air pollution potential, especially in small valleys where there is a propensity for stagnation of overhead air masses. The Panel believes these effects can largely be averted if proper investigations are made and if cooling towers are sited properly.

Conclusion: Cooling towers, if not properly designed and sited, may have a number of adverse effects. In order to adequately evaluate the total environmental effects of alternative cooling systems, serious consideration must be given to atmospheric impacts.

Recommendation: The Panel recommends that climatological and meteorological studies be required sufficient to delimit within practical engineering and economics the potential effects of each type of cooling alternative on the atmosphere.

In the operation of cooling towers, a number of chemicals are used as corrective measures to prevent or reduce such things as wood deterioration, biological growths, corrosion, scaling, and general fouling. These chemicals, as well as others naturally occurring in water, tend to become concentrated by evaporation and are released to water bodies as what is termed blowdown. Blowdown becomes an industrial waste which must then be subject to control under water quality standards.

Recommendations: 1. The Panel recommends that possible pollution caused by blowdown be identified in detail along with proposed control measures in analyzing cooling system alternatives in such a manner that it can be adequately evaluated by those Federal and state agencies having jurisdiction over water quality standards and plant siting. This should extend to consideration of the effects of the use of various metal alloys for condenser tubing.

2. Because the possible water quality problems identified above could be mitigated with the development of better corrective measures, the Panel recommends that research be undertaken to develop designs, processes, chemicals, and materials to minimize environmental impact.

One direct effect of cooling towers is that their use lowers the efficiency of the power plant thereby requiring either (1) more fuel input at the plant or (2) more plants overall, to make up for the lost energy production. This then becomes a necessary part of evaluating (1) future energy demands and (2) the total environmental impact of this, or any, type of cooling facility.

Evaluation of Total Heat Assimilation Capacity

The Commission is well aware of the increasing difficulty being experienced by electric utilities in obtaining the necessary licenses and permits to construct steam electric power plants. The Panel believes that in addition to concern (and frequently opposition) being expressed over the environmental impact of one plant or of one unit, there is a great deal of underlying concern over the possible impacts of a number of plants or units over a long period of time. While one unit may not have a serious environmental impact, a number of future additions may.

The Panel believes that when a site is being evaluated initially the probable maximum waste heat assimilation capacity of the receiving waters should be assessed.[1/] This could go a long way toward maintaining credibility between the applicant and those who fear that once one unit or one plant is constructed, the area has been "softened up" for all future proposals.

Recommendation: A site should be evaluated on the basis of the ability of the receiving waters to assimilate heated discharges in order to delimit, based on the best information currently available, the maximum allowable heat input in terms of environmentally compatible BTU's of input energy to the receiving waters.

Steam Electric Power Plant Siting Alternatives

A broad range of possibilities in siting future power plants exists. Many of these are presently under study by industry and

1/ The magnitude and possible effects of the total heat release to air as well as water should be assessed in each case. See p. 10, "Heat Pollution."

government agencies. The Panel recognizes that while water resources are only one consideration in siting, the potential impacts are of major concern and, therefore, should be given detailed evaluation.

Simulation and Predictive Modeling

An important aspect of site evaluation is the need to assess the probable impact of various cooling system alternatives on the desired use of the water resource. Simulation and predictive modeling techniques, while still in the embryonic stages of development, show significant promise for describing thermal life support system interaction and the processes governing heat movement in aquatic systems. The continued development and refinement of these techniques should be supported with a view to their leading to (1) better definition of possible problems before plants are designed and constructed, and (2) better heat discharge designs to mitigate adverse environmental impacts.

Conclusion: In order to more adequately assess the effects of steam electric power plants on the water environment, high priority must be placed on developing and validating predictive models relating to (1) thermal life support system interaction and (2) the processes governing heat movement in aquatic systems.

Recommendations: 1. The Panel recommends that the Federal-state-industry task force, the establishment of which was recommended earlier, be charged with the responsibility of maintaining a continual assessment of predictive technology and be jointly funded by the Federal Government and industry to do in-house and/or let contract studies to complete gaps in present methods and to research new approaches as the need for them is identified.

2. The Panel also recommends that this task force be made the clearinghouse for information on this aspect of siting.

Pre- and Post-Operational Studies

Another important aspect in assessing the possible impact of heat on the water environment is the opportunity to learn from actual experience gained in power plant operation. This can be most meaningful if carried out through a regularized process of pre- and post-operational investigations and monitoring studies correlated with the predictive modeling mentioned earlier. This would allow the comparison of actual effects with those predicted and thereby allow a refinement of modeling techniques which would in turn lead to better plant designs. The Panel endorses the emerging view that pre- and post-operational investigations and monitoring studies be required at all new plant sites and existing plants planned to undergo future expansion. These studies should be conducted so as to provide needed information on the effects *in situ* of imposing a power plant discharge on the water environment; this would then aid in assessing effects of future sites and in evaluating a range of condenser cooling alternatives. While this activity should be funded and managed by the company(ies) constructing and operating the plant, the information developed should (1) become part of the broader ecological research program suggested herein, and (2) become input to the information and data center the establishment of which was recommended earlier.

Recommendation: Pre- and post-operational investigations and monitoring studies should be required at all new power plant sites and existing plants planned to undergo future expansion.

Siting Alternatives

Although there is currently a great deal of attention on new siting alternatives, a large number of future power plants using present technology will undoubtedly and justifiably locate on inland rivers, natural lakes, man-made impoundments, and along the coast.

Generalizations concerning something which is site-specific are frequently of little value to decisionmakers. The Panel does believe, however, that there are several important broad guidelines which should be used in siting a steam electric power plant.

1. Heated water discharges should not be released in such a way as to interfere with the migratory activity of aquatic biota or seriously impair the movement of important species.

2. Plants without auxiliary cooling systems should not be located at the mouths of tributary streams which are used for spawning purposes by migratory species.

These guidelines should be reflected in the establishment of water quality standards.

A number of possibilities exist for previously untried combinations of separately proven concepts as well as completely new concepts. A number of studies and proposals have been made for siting nuclear plants in ocean, coastal, and estuarine areas.[1/] These

1/ In discussing ocean, coastal, and estuarine siting, the Panel refers to (1) ocean siting as siting on or in the ocean, (2) coastal siting as land-based plants on smooth or relatively smooth shorelines with ocean outfalls, and (3) estuarine siting as siting in areas where there is a mixing of fresh and salt water such as embayments with coastal drainage and/or upland river inflow and unrestricted river entrances.

include floating power plants, power plants constructed on man-made islands on the continental shelf, as well as underwater plants resting on the ocean floor. In addition to placing less of a demand on fresh water sources, i.e., consumptive loss is no problem, the heated discharges may provide some positive benefit. The upwelling of heated water may push the nutrient-laden lower layers to the surface and through this overturning enhance the fishery resources. Siting alternatives of this type deserve special attention for the intermediate and long term.

If placed far enough in the ocean, heated discharges will be dispersed by the ocean currents and diffused into the large volumes of water available. In order to minimize environmental impact, however, it is important that they be discharged beyond the surf zone and also not in areas where littoral drift and/or near shore currents will return the heated waters to the shoreline, with the exceptions of those areas where net benefits are known to exist.

In addition, a number of plants have been and will likely continue to be proposed for estuarine areas. The Panel believes that a much larger range of problems presents itself in this case. Estuarine areas, besides predictable esthetic disadvantages, because of their delicate ecological balances, are generally much more susceptible to damage through man's activities than many other areas, and should therefore be viewed with caution.

Presently untried is the possible combination of pumped-storage with nuclear power generation either above or below ground. Variations of this could possibly use waste treatment plant effluent as

a water source with ultimate cooling water disposal through deep ocean outfalls or through pump-back as in pumped-storage developments. Other siting possibilities include multiple use developments which are being pioneered now in some areas of the Nation. Obviously, developments of this type must be completely engineered at the outset and require rather large R&D effort as well as a source of venture capital. Although perhaps these innovative combinations are categorized as longer term, the Panel believes they should be given early study and evaluation.

Conclusions: 1. Coastal and ocean siting present a number of alternatives for siting future nuclear power plants.

2. Estuarine areas, however, because of their delicate ecological system should be viewed with caution and require more sophisticated and exhaustive study because of their many cause and effect relationships.

Evaluation of New Siting Alternatives

The Panel emphasizes that many of the possible siting alternatives are presently in the category of possibilities. It is important that the potential benefits of the alternatives and their probabilities of success be assessed. An adequate amount of pivotal R&D effort needs to be expended to provide these assessments. Site evaluations should include technical, economic, environmental, and social considerations.

Recommendation: Research and development on a number of new siting alternatives should be immediately undertaken in sufficient detail to determine their potential benefits and their probabilities of future success.

Power Plant Siting and Water and Related Land Resources Planning

From the foregoing discussion, it is readily apparent that steam electric power plants can have significant impacts on the Nation's water and related land resources. Cooling water requirements, consumptive use, and water quality, especially temperature standards, are all important aspects of total water management. As mentioned earlier, the evaporation of extensive quantities of water represents a possibly serious consumptive use of water, especially in the Nation's water-short areas, and during peak power-low flow periods. Water resources planning should take into account these possible modifications in the normal hydrology. Also, water quality standards should be set and continually reviewed in light of a broadly-based water resources planning effort.

Although these considerations are not new to water resources planners, they have not generally been accorded the special study which we believe is warranted, particularly in light of broad environmental considerations. Greater attention to power generation in water resources planning would allow a broader focus on the quality-quantity relationships involved in plant siting; it would also provide a much needed closer tie between water resources and land use planning, of which power plant siting is an important consideration.

In most present water resources planning studies, the power considerations include (1) an estimate of future power demands,

(2) an evaluation of hydroelectric power potential, and (3) projections of water withdrawals and consumptive use, usually on a gross-regional basis. More in-depth consideration and a broader focus is needed, however, if the full implications of regional and subregional power generation are to be adequately reflected in water resources investigations covering the affected water bodies. While steam electric power plants can be considered as just another industrial facility, the large withdrawal requirements and consumptive use possibilities justify special attention at a level of detail not necessary for most manufacturing plants.

The manner in which a broadly-based consideration of energy production in water resources planning is achieved will vary somewhat according to the group(s) doing the planning. To assist water resources planning entities in broadening their focus, we believe additional policy and procedural guidance is needed. An appropriate group to provide this guidance is the U.S. Water Resources Council (or whatever institutional arrangement the Commission may recommend to assume the statutory authority of the Council). We believe the Council should establish a work group of agency representatives to advise planning entities on the approach to be taken in the broadly-based water and related land resources planning studies.[1/] The steps

1/ We emphasize that we are not recommending that these groups assume responsibility for power plant siting or assume any responsibilities for issuing withdrawal permits or approving water quality standards now under state agencies, but that since siting is such an important consideration in land and water planning it should be given major attention before rather than after the decisions concerning siting have been made.

to be taken by the field planning entities should then be outlined in the Plan of Study which is normally developed to guide study participants.

Conclusion: Water resources planning studies should be broadened in focus to include greater consideration of steam electric power generation and its possible effects on the water environment, particularly with respect to water quality, water withdrawals, and consumptive use.

Recommendations: 1. We recommend that the river basin and compact commissions, interagency coordinating committees, and other such bodies undertake, in cooperation with private interests, a comprehensive power/environment program in an attempt to better plan and manage our land and water resources.

2. We recommend that the Water Resources Council establish a work group of agency representatives to provide policy and procedural direction on how to reflect water resources aspects of power plant siting in water resources planning and related investigations. We believe the recommendations of this group should be implemented by requiring that the Plan of Study for future water and related land resources studies include a detailed statement of the means by which power generation, particularly its effects on water quality, water withdrawals, and consumptive use, will be considered in the planning effort.

Potential and/or Developing Technologies

The quantities, locations, and effects of waste heat on the water resource are very dependent on the following technologies: generation technology--which indicates through its energy conversion efficiency the amount of heat to be discharged; cooling technology--which determines how the heat is to be transferred from the condenser to the atmosphere; and transmission technology--which has an impact on where the generating facility is located thereby locating the source of the heat discharge. Potential beneficial and multiple

use technologies are also important from the viewpoint of their possible effect on reducing waste heat discharge and/or combining waste heat discharges with other inputs in fully designed systems. Each of these are addressed in the above order.

Generation[1/] Nuclear power is expected to play an increasing role in meeting the electrical energy needs of the United States with 50-75 percent of total capacity by 2000. The greatest portion of this is expected to be generated by light water nuclear reactors, 30-40 percent of total capacity, with high temperature gas-cooled reactors comprising 10-20 percent of total capacity. Nuclear breeders may well be providing 10-15 percent of total capacity by year 2000. Breeder technology, while having a higher efficiency than the current average efficiency of steam electric generation, will approximate an efficiency of only 38-42 percent. While it does have other advantages such as no chemical or particulate air pollution, more efficient use of uranium and thorium, and conservation of fossil fuel resources, it will provide little relief from the overall waste heat problem.

Under present planning assumptions, the thermal energy of a breeder reactor is to be converted to electrical energy using conventional (steam turbine) Rankine cycle technology. However, efficiencies using this cycle are limited because the limitations of metals involved preclude obtaining steam temperatures much in excess

1/ See Table 3, p. 25.

of 1050°F, the equivalent of an available fossil fuel steam plant. Since the primary thrust of breeder development has been that of providing a large bulk heat source, the development of supporting power technology using advanced cycles of higher efficiency has not been accorded the degree of attention which the Panel believes is warranted. Greater emphasis should be placed on achieving the goal of higher efficiency by developing the supporting technology for advanced cycles and an early replacement of the Rankine cycle.

A promising technology which represents a potential revolutionary change in future power systems is the fuel cell. It is a device which converts the chemical energy in gaseous fuels directly to electrical energy, thereby avoiding some of the heat engine efficiency limitations imposed by the second law of thermodynamics. It is not a large central station generation method and therefore lends itself to unique possibilities such as small-scale units for apartment houses, shopping centers, and small residential areas. The Panel does not believe the present modest developmental effort on the fuel cell and supporting gas fuel supply research is consistent with what the national interest should be in its development. We believe an accelerated R&D program is warranted.

Magnetohydrodynamics (MHD) is another promising technology. Instead of a solid conductor rotating in a magnetic field, a jet of high-temperature high-velocity ionized gas is forced through a magnetic field. By placing electrodes in this hot gas stream, direct current at relatively high voltages can be obtained. MHD can

be used as a topping cycle for conventional steam cycles or by itself; either way the efficiency is 40-50 percent higher than with present fossil fuel plants and would therefore have a significant effect in reducing heat rejected to the atmosphere. A number of serious developmental problems remain, however, and the Panel does not see MHD as being a large contributor to the Nation's generating capacity in the near term.

For the longer term, more efficient generation technologies appear to hold promise. The most promising is fusion power which appears to go the farthest in reducing waste heat discharges. Although it is difficult to assess the quantity of waste heat discharge, it is expected to range from 5-25 percent of the total heat generated, a significant reduction from present technology. Even with an expanded R&D program, however, it is not expected to be a major contributor to central station technology before 2010.

Conclusion: While the Panel encourages the development of more efficient generation systems, it does not, under present and probable future development schedules, see new technologies in generation as having any significant impact on waste heat discharges in the near to intermediate term, that is, before the turn of the century.

Recommendations: 1. The Panel recommends a greatly expanded R&D program on the high potential short-intermediate term technologies, i.e., the fuel cell, MHD, and the breeder in addition to development of more efficient steam cycles.

2. Since nuclear fusion holds a number of advantages, the Panel recommends a continuance of at least present levels of funding, and once the breeder is developed, to shift the nuclear research dollar from the breeder to the fusion process. This would, of course, depend on an assessment of the potentials in new technologies at a later time.

Cooling

The potential for reducing the heat discharge to water bodies through the development of new technologies in cooling systems at present generally lies in improvements to systems already developed or under development. No revolutionary designs appear on the horizon. The substantial improvements possible in the planning and design of known systems include such things as improved intake and discharge systems, more efficient and more environmentally compatible cooling towers, and better dispersion and diffusion methods thereby allowing greater use of once-through cooling.

The development of efficient economical large-sized dry cooling towers would have the most significant impact since with dry towers there would be a negligible consumptive loss and no heat discharge to water; for cooling these towers depend on the convective transfer of heat to the air as it passes through a fin-tube heat exchanger, rather than on evaporation. Unfortunately, present dry tower designs range from $18-$32 per KW in capital cost (as opposed to $2-$5 per KW for once-through systems, $4-$9 per KW for cooling ponds, and $5-$13 per KW for evaporative cooling towers) and are quite costly to operate and maintain, especially since they reduce the plant's average annual energy output by six to eight percent (and require the construction of an additional 12-16 percent installed capacity).[1/] Design

1/ U.S. FEDERAL POWER COMMISSION (1972), #14, p. I-10-8. These investment costs represent ranges derived as of the year 1969. Future construction costs will probably be higher. If cooling towers are added to existing plants, the costs of backfilling will be higher still.

breakthroughs in lowering the cost of dry tower cooling, if achievable, could be of great significance. It is important to point out, however, that there may be basic physical problems such as the much greater inefficiency of air as a cooling medium and the possible environmental impacts from discharging dry heat from large point sources.

Conclusion: Although no new cooling system designs appear on the horizon, there may be a great potential for substantial improvements in systems presently in use and under development.

Recommendation: The Panel recommends an accelerated R&D effort on cooling technologies with a view to (1) capturing potential improvements in existing systems and (2) developing an efficient economical large-sized dry cooling tower.

Transmission

New transmission technologies have the potential of allowing much greater flexibility in siting power plants, thereby providing a broader range of more economical alternative site locations from which to choose. For instance, these technologies may allow the more economical location of power plants long distances from load centers in order to take advantage of more abundant water supplies. They would also help make beneficial and multiple use technology more economical where such uses involved resource opportunities far removed from major metropolitan and power load centers.

Until recently, it has been uneconomical to transmit power over long distances because of excessive lines losses which in turn increase power generation requirements. Recent developments, however, have now made possible the aboveground long distance transmission of

very high voltage direct current with only moderate losses. Since esthetic factors have become quite important in transmission line construction, there is increasing pressure to place transmission lines underground. Under present technology, however, underground or underwater transmission is quite costly, including a greater line loss potential, with estimates ranging from ten to forty times the cost of overhead lines. The Panel believes that the technical problems are not insurmountable and that further research and development, together with the transmission of large amounts of power, may bring the unit costs of underground transmission down to a much more economical level.

In addition to underground transmission, the development of such things as superconductivity, SF_6 gas-cooled transmission, and the combined cryogenic electrical and liquified gas concept would be significant breakthroughs in allowing greater flexibility in the consideration of siting alternatives.

Conclusion: The development of improved economical transmission technology would lend much greater flexibility to plant siting which could then have a significant impact on the flexibility of power plant siting alternatives and therefore the location of waste heat discharges. Other benefits such as reduced lands and easements required, better esthetics, and multipurpose use of utility corridors are also likely.

Recommendation: The Panel recommends an accelerated R&D program on transmission technologies.

Beneficial Use Technology

In general, recycling or reuse of waste products present a number of interesting and desirable possibili-

ties for the future. In this vein, a wide range of applications for beneficial uses of waste heat from steam electric power plants have been identified and investigated. This concept has been the subject of a number of recent conferences and contract studies. Possibilities have been suggested for the use of heated water in aquaculture, mariculture, agriculture, airport defogging and deicing, deicing of shipping lanes, extending the recreation season, acceleration of sewage treatment, space heating and air conditioning, and for industrial processes. Its uses in multipurpose systems are discussed in the next section on multiple use technology.

The Panel believes that viewed from the perspective of trying to solve the waste heat problem, beneficial uses must either (1) reduce adverse effects on the water environment or (2) provide an economic gain or payout to help allay the cost of necessary special cooling systems. Unfortunately, there are a number of constraints which make it difficult for either of these criteria to be met.

With respect to the first point, it should be emphasized that "use" of waste heat does not reduce the amount of heat to be rejected. All energy, whether "wasted" or "used" is eventually rejected to the biosphere. On the second point there are a number of problems. One is the relatively low quality heat available in the cooling water discharge. Normal maximum temperatures range from 90°F to 100°F, with a high of 120°F. Most potential users (one exception being sprinkler irrigation) require a much higher temperature for efficient

utilization systems. A second problem is the large quantities of low grade heat produced. For instance, it has been estimated that to use the waste heat from a 1,000 MW plant for food processing would require 70-80 ordinary-sized food processing plants,[1/] and if used for greenhouse agriculture could heat 4.4 square miles of greenhouse.[2/] Thirdly, there is frequently quite a difference in the timing of maximum heat discharge and of the need for waste heat. Furthermore, even though waste heat may be available when needed (if the plant is operating), a large part of the time the heat may not be needed; auxiliary cooling would, therefore, still be required. An example would be where heat is needed only infrequently as with airport defogging and deicing. Fourthly, while certain technologies have a potential for use in connection with completely engineered new systems such as space heating and air conditioning, new cities development and multipurpose agro-industrial complexes, many are beyond engineering and economic practicality when trying to apply them to existing systems. Fifthly, a potential problem with any beneficial use technology is the possibility of a forced shutdown of the power plant thereby eliminating the waste heat supply.

A related development with considerable potential is the "total energy" concept. This involves an on-site electrical energy generation system which captures the waste heat produced and converts it into steam or hot water and uses this byproduct for heating, air

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1/ GARTON, Ronald R & CHRISTIANSON, Alden G (1970), #4, p. 218.
2/ BELL, Robert A et al. (1970), #2, p. 203.

conditioning (through such things as absorption chillers), and domestic hot water. This non-central station generating technology would, like the fuel cell, provide a revolutionary alternative to present trends of larger central station generation and point source waste heat discharge.

Although for the reasons stated above, the Panel sees beneficial use technologies as providing little relief from the waste heat problem over the next 15 years, we do not wish to leave a pessimistic view concerning the longer term. Continued research and development in many areas may achieve breakthroughs which could completely change the economic practicality of some uses. At present, waste heat utilization in aquaculture, agriculture, and space heating and air conditioning appear to hold the greatest promise. Certainly the potential for beneficial use technology further suggests the need for a broader view of energy as a resource and the need to emphasize more efficient use of energy and energy generation byproducts.

Conclusions: 1. While beneficial uses of waste heat should be looked upon as a possible help in reducing heat discharge to water bodies, they cannot be counted on to provide any significant relief from the waste heat problem in the near term and then only on a localized basis. Furthermore, it is likely that where waste heat utilization is employed, some type of supplemental cooling system will still be required if such a system would otherwise have been required to meet applicable water quality standards.

2. For the longer term, however, the possibilities appear more attractive. Waste heat utilization planned as part of an urban energy center appears to have significant potential. The Panel emphasizes, however, that this type of development should not be considered as an add-on to an existing system but must be planned as an integral part of a completely engineered new system.

Recommendations: 1. The Panel believes that for reducing the waste heat problem, of all the presently identified uses, waste heat utilization in agriculture, aquaculture, and space heating and air conditioning for new residential, commercial, and industrial developments holds the greatest promise for the future, and should be the focus of future R&D activities.

2. The Panel recommends that if the new cities program progresses to the implementation stage, a detailed engineering and economic study be made of the possibility of incorporating beneficial use technology to develop the new city as an urban-energy center. Space heating and air conditioning should be the primary focus with related studies on the potential for incorporating greenhouse agriculture and aquaculture.

Multiple Use Technology

A number of possibilities also exist for incorporating the location and operation of steam electric generating plants with the operations of industrial plants, the production of agricultural commodities, mineral and mining processes, desalting (which we understand is the subject of another Commission study), as well as commercial ventures. Obviously, developments of this type can seldom be "add-on" processes. For greatest efficiency they must be completely engineered at the outset. Developments of this type have a number of possible advantages, the most significant to this study being more efficient use of the Nation's energy resources and use of the waste heat produced from the electrical energy generation process.

Although there are technical and legal problems associated with both beneficial and multiple use technology, one of the most serious obstacles is bringing together those people who are involved in the

diverse developments which have the potential for being incorporated into an integrated designed, managed, and operated system.

Conclusion: There are a number of potential benefits to be achieved with the integration of electrical energy plants and the development of agro-mineral-industrial-commercial complexes including desalting plants using both the electricity and the waste heat generated.

Recommendations: 1. The Federal Government should encourage the consideration of promising integrated energy-agro-mineral-industrial complexes in future siting studies with a view to more efficiently utilizing the Nation's energy and water resources.

2. The opportunities and potentials of integrated energy systems should be investigated as part of the research effort recommended in the following section. This research should include studies of institutional arrangements and possible legal problems.

Research and Development

The Panel has identified two needed thrusts for future R&D. The first, research for the purpose of determining environmental impact and setting environmental standards, was discussed earlier. Recommendations were made for the organization and management of that research. In this section of our report we focus on the other aspects which require a major research and development effort. These include:

More effective chemical and/or mechanical processes in the operation of cooling systems (p. 43, 45)

An early assessment of the probabilities of new siting alternatives (p. 51)

Power generation technology (p. 57)

Cooling system technology (p. 59)

Transmission technology (p. 60)

Beneficial use technology (p. 64)

Multiple use technology (p. 65)

The funds needed for research and development are large and will require funding levels significantly greater than those currently provided by government and industry. The recent report of the R&D Goals Task Force to the Electric Research Council (ERC) pointed out that to achieve the R&D goals which the task force identified calls for a $30 billion commitment over the next 29 years, a figure approximately double the current level of combined expenditures of government, manufacturers, and utilities.[1/] The report also pointed out that "Present levels of R&D simply will not enable our industry to do what it must do to meet growing demands for electrical energy in ways environmentally acceptable."[2/] While the Panel has not made a detailed independent assessment such as the ERC task force effort, the level of funding suggested and the broad focus of R&D activities it identified are realistic estimates of the magnitude and scope of the R&D effort needed.

The recent OST study referred to earlier provides a good perspective on the funding aspects of this R&D.

1/ ELECTRIC RESEARCH COUNCIL (1971), #3, p. 2. The Electric Research Council was organized in the spring of 1965 to provide a means by which the various segments of the electric utility industry in the United States could join in cooperatively supporting research of industry-wide importance. The Council consists of 12 industry executives--eight from the investor-owned sector and one each from the United States Department of the Interior, the Tennessee Valley Authority, the American Public Power Association, and the National Rural Electric Cooperative Association.

2/ Ibid. An ERC task force on R&D Financing is now studying ways of implementing the R&D Goals report.

> "Development of new environmental protection systems often entails the fabrication and demonstration of large facilities frequently costing on the order of tens of millions of dollars.... The results of such R & D efforts are products which can be sold to the utilities so equipment manufacturers and process firms are a source of ideas and funds. Unfortunately, the costs of demonstrating such systems are frequently so high that outside funding must be obtained. Here the utilities singly or in groups can play a major role. The federal government should also contribute to such efforts in order to underwrite some of the uncertainty and to insure that the results are generally available.
>
> "Development of major new energy conversion systems such as the breeder reactor, MHD and combined cycles involve even larger expenditures on the order of hundreds of millions even billions of dollars. Funding such large projects may well require the combined efforts of the equipment manufacturers, the utilities and the government."1/

In addition to the more traditional approaches to funding, another approach has been identified which merits careful consideration. The establishment of an energy/environment R&D fund, funded through imposition of a surcharge or tax on all energy consumers has been proposed and supported by a broad range of individuals and groups and is the subject of proposed Federal legislation. This funding could be on the basis of (1) a percentage of the total electric bill, (2) a surcharge per kwh generated, or (3) a surcharge per million BTU's on consumed fuel or nuclear equivalent. For example, to provide approximately $200 million per year would require (1) a one percent surcharge on electric bills, (2) a 1/75 of a cent/kwh surcharge on electrical consumption, or (3) a 0.4 of one cent

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1/ U.S. OFFICE OF SCIENCE AND TECHNOLOGY (1970), #17, p. 42.

surcharge per million BTU's (released as energy in the fuel).[1/] This would correspond to an annual per capita increase in the cost (directly through residential use and indirectly through commercial and industrial use) of electrical energy of approximately $1.00. The Electric Research Council is presently holding regional meetings throughout the country at which individual electric utility companies and regulatory agencies are being asked to support an expanded R&D effort something along the lines as suggested above.[2/]

The OST report referred to earlier suggests another important aspect of future funding. Although recent actions by the electric utility industry indicate an increase in industry-supported R&D, we generally concur with the OST finding that:

> "The general level of research and development expenditures by electric utilities and particularly with respect to environmental matters is far below an appropriate level for an industry of this size. This anomaly can be attributed in large measure to the regulatory control on profits and the public service role of industry."[3/]

In light of the above, we also support the view of OST to:

> "...urge the regulatory commissions at the federal and state level to take positive action to assure that the utility industry can recover R & D expenses in the rates and that the utilities devote a reasonable portion of their large revenues to such expenditures."[4/]

1/ Based on 1970 electrical energy generation of 1,530 billion kwh. The fund would increase to over $400 million per year by 1980 based on the forecasts given in Table 1.

2/ ERC was incorporated on March 23, 1972, as the Electric Power Research Institute Inc. and plans are under way to seek rate relief equal to an assessment of 1/10 mill per kwh on investor-owned utilities to provide the funding for the Institute. Consideration is also being given to how to collect from the non-investor-owned utility members of ERC.

3/ U.S. OFFICE OF SCIENCE AND TECHNOLOGY (1970), #17, p. 42.

4/ Ibid., p. 44.

Energy/environment R&D is a good example of where research other than what is identified normally as water resources research will likely be of major significance to water use and management. Obviously, the design of funding and institutional arrangements for energy/environment R&D will depend on a number of factors and should be undertaken to solve a number of problems, only one of which is water resources. The Panel believes its role in this matter to be one of pointing out to the National Water Commission the scope and probable magnitude of the R&D effort required to provide the technological base for future energy generation and related aspects as they might affect future water problems and demands.

An analysis of specific funding levels and institutional arrangements necessary for the conduct of this research, while of interest to the Panel, was considered beyond the scope of the charge given to the Panel. While individual Panel members have views on how to provide the R&D thrust necessary, the Panel has not reached a consensus on a "best method" of R&D funding and organization. We emphasize, however, that for the intermediate and long term, R&D, hopefully leading to better technologies in the areas identified in this report, is a critical aspect in achieving compatibility in meeting future energy needs and at the same time maintaining the quality of the total environment.

Overview

Possible water problems caused by steam electric power plant operation are typical of many problems facing society which find their causes and their most likely solutions in a spectrum of diverse areas of interest. The waste heat problem is also typical in that there is not now, and doubtfully ever will be, a single answer to fit all cases.

In analyzing the problems identified in this report, it becomes apparent that two perspectives were needed. One perspective must deal with the near to intermediate term, a period of time during which power plants will be sited based generally on currently proven and available technology. This time period is expected to include most of the remaining part of the twentieth century. The Panel has laid out what it believes is necessary to insure the proper inclusion and consideration of the water resources impacts when the necessary balancing judgments are being made.

The second perspective must deal with that time beyond when research and development efforts might have a significant effect on the whole issue of energy generation and waste heat discharge. If new technologies are introduced, it is quite possible that the problems with which we must deal in the next twenty to thirty years will no longer be problems, at least in as great a proportion as those presently perceived.

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